US010731478B2

(12) **United States Patent**
Xu et al.

(10) **Patent No.: US 10,731,478 B2**
(45) **Date of Patent: Aug. 4, 2020**

(54) **TURBINE BLADE WITH A COUPLED SERPENTINE CHANNEL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/217,953**

(22) Filed: **Dec. 12, 2018**

(65) **Prior Publication Data**

US 2020/0190998 A1 Jun. 18, 2020

(51) **Int. Cl.**

F01D 5/18 (2006.01)
F01D 5/30 (2006.01)
F01D 5/14 (2006.01)

(52) **U.S. Cl.**

CPC ***F01D 5/188*** (2013.01); ***F01D 5/141*** (2013.01); ***F01D 5/187*** (2013.01); ***F01D 5/3015*** (2013.01); *F05D 2220/32* (2013.01); *F05D 2260/205* (2013.01); *F05D 2260/22141* (2013.01); *F05D 2260/232* (2013.01)

(58) **Field of Classification Search**

CPC F01D 5/141; F01D 5/187; F01D 5/188; F01D 5/3015; F05D 2220/32; F05D 2260/205; F05D 2260/22141; F05D 2260/232

See application file for complete search history.

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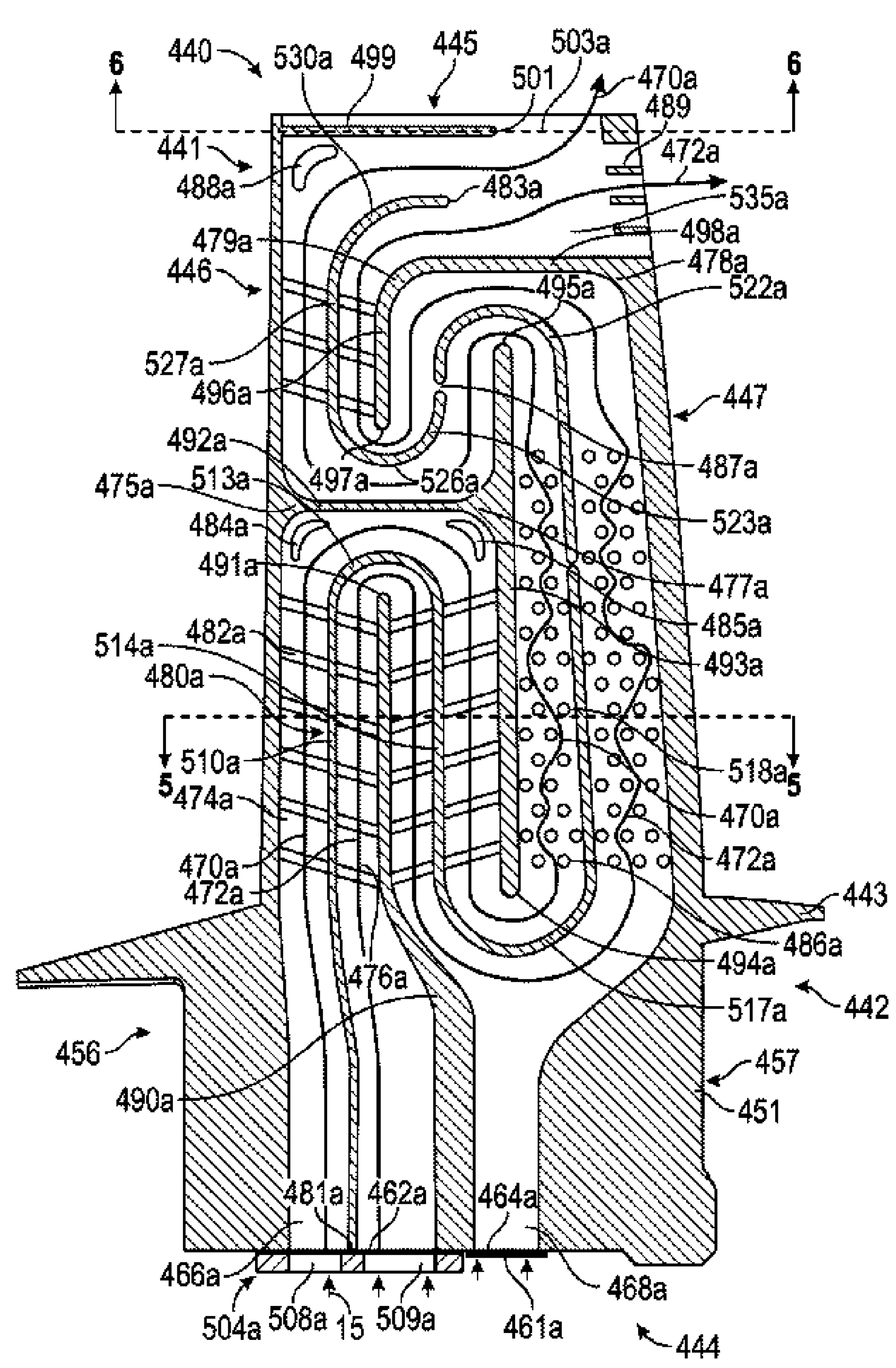
(57) **ABSTRACT**

A turbine blade having a base and an airfoil, the base including a root end. The airfoil including a skin extending from the base and defining a first edge, a second edge, having a tip end opposite from the root end. The turbine blade further including a base rib extending from the base and into the airfoil, a center divider extending from adjacent the first edge towards the second edge, a center rib disposed between the center divider and the second edge, extending from adjacent the center divider towards the tip end and extending from adjacent the center divider towards the root end, a tip center rib extending from adjacent the second edge towards the first edge, a tip rib extending from adjacent the tip center rib towards the base, a dividing rib and a first channel.

20 Claims, 6 Drawing Sheets



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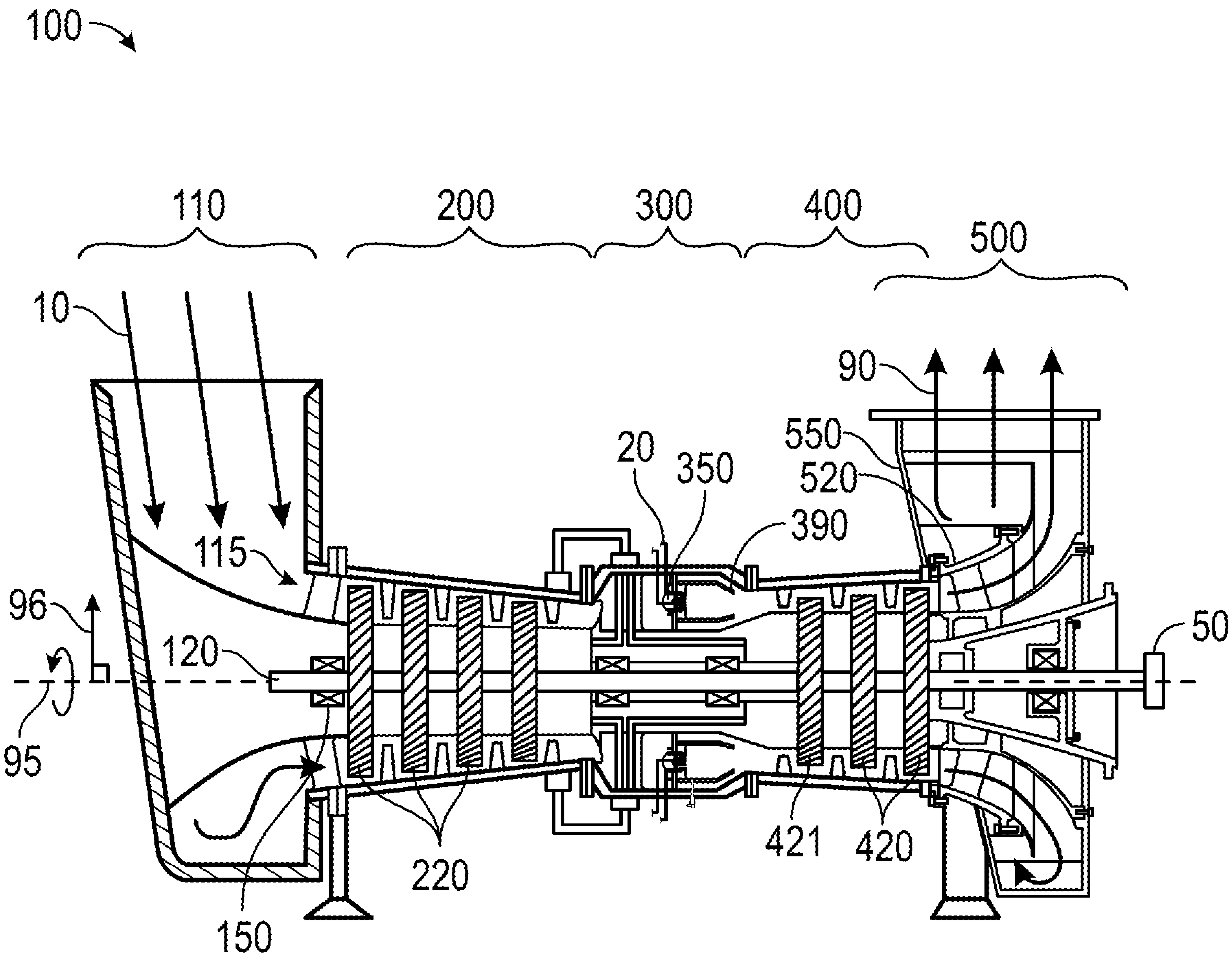


100
110
200
300
400
500
10
90
550
520
20
350
390
115
96
120
50
95
220
421
420
150

FIG. 1

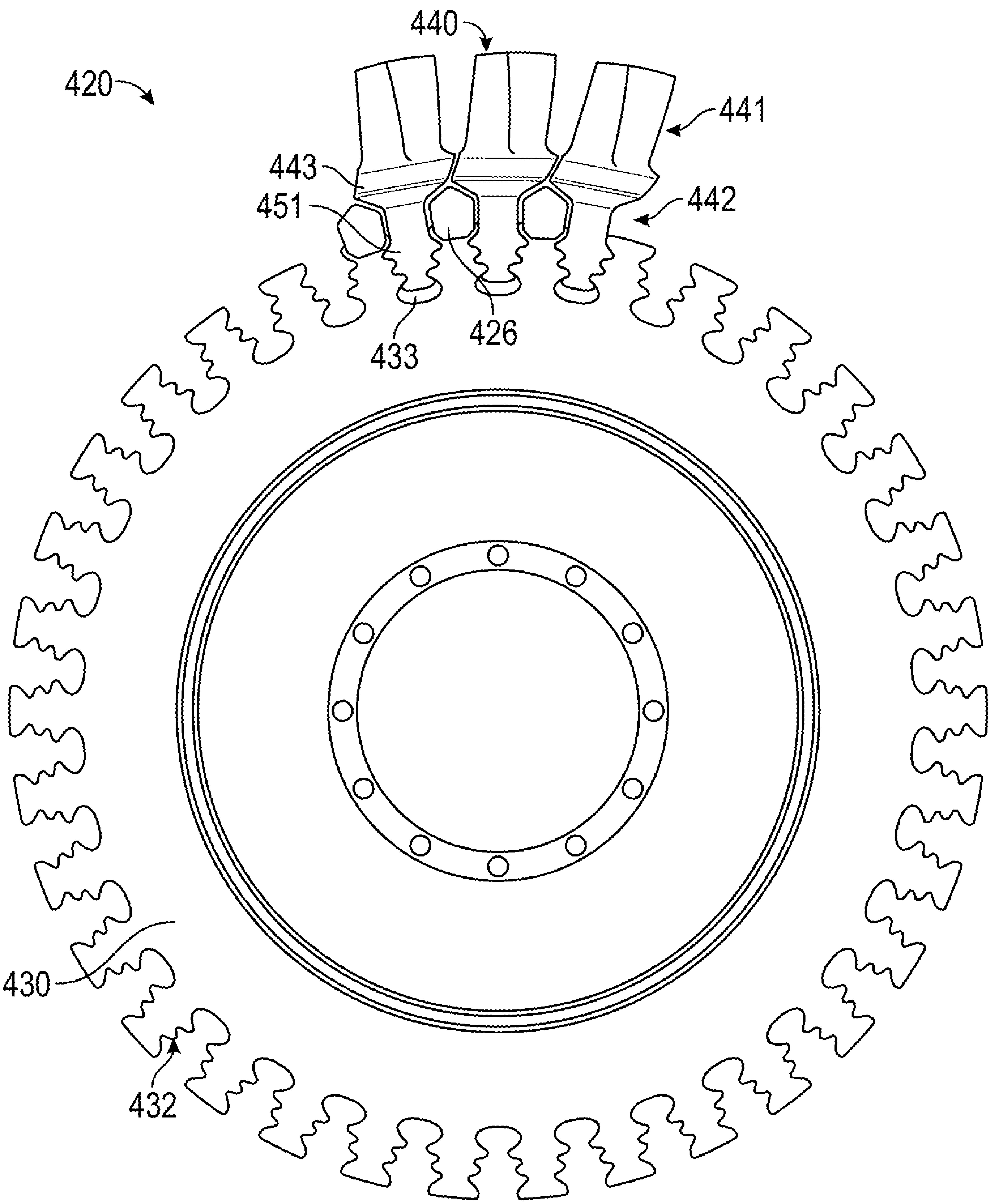
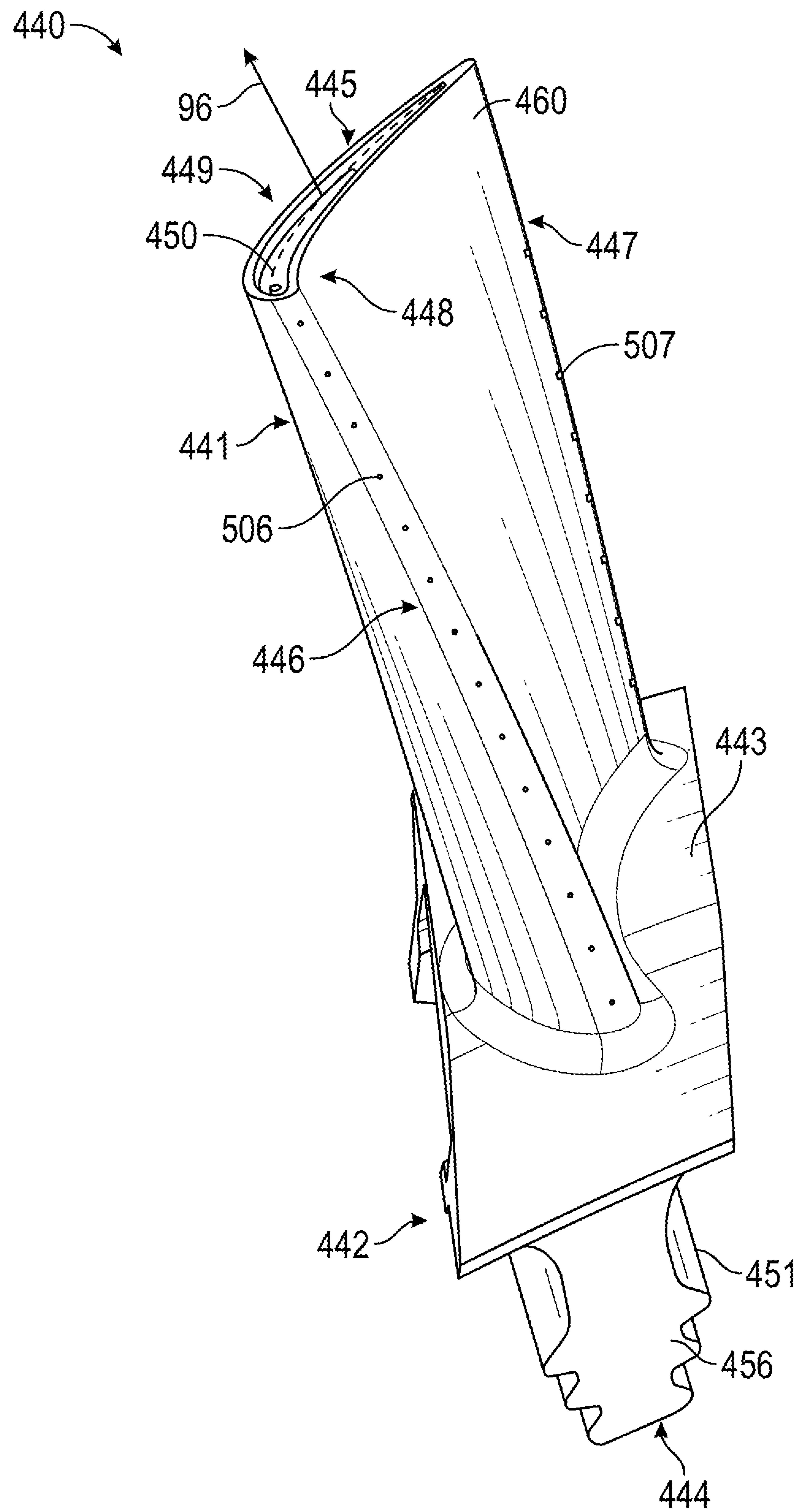


FIG. 2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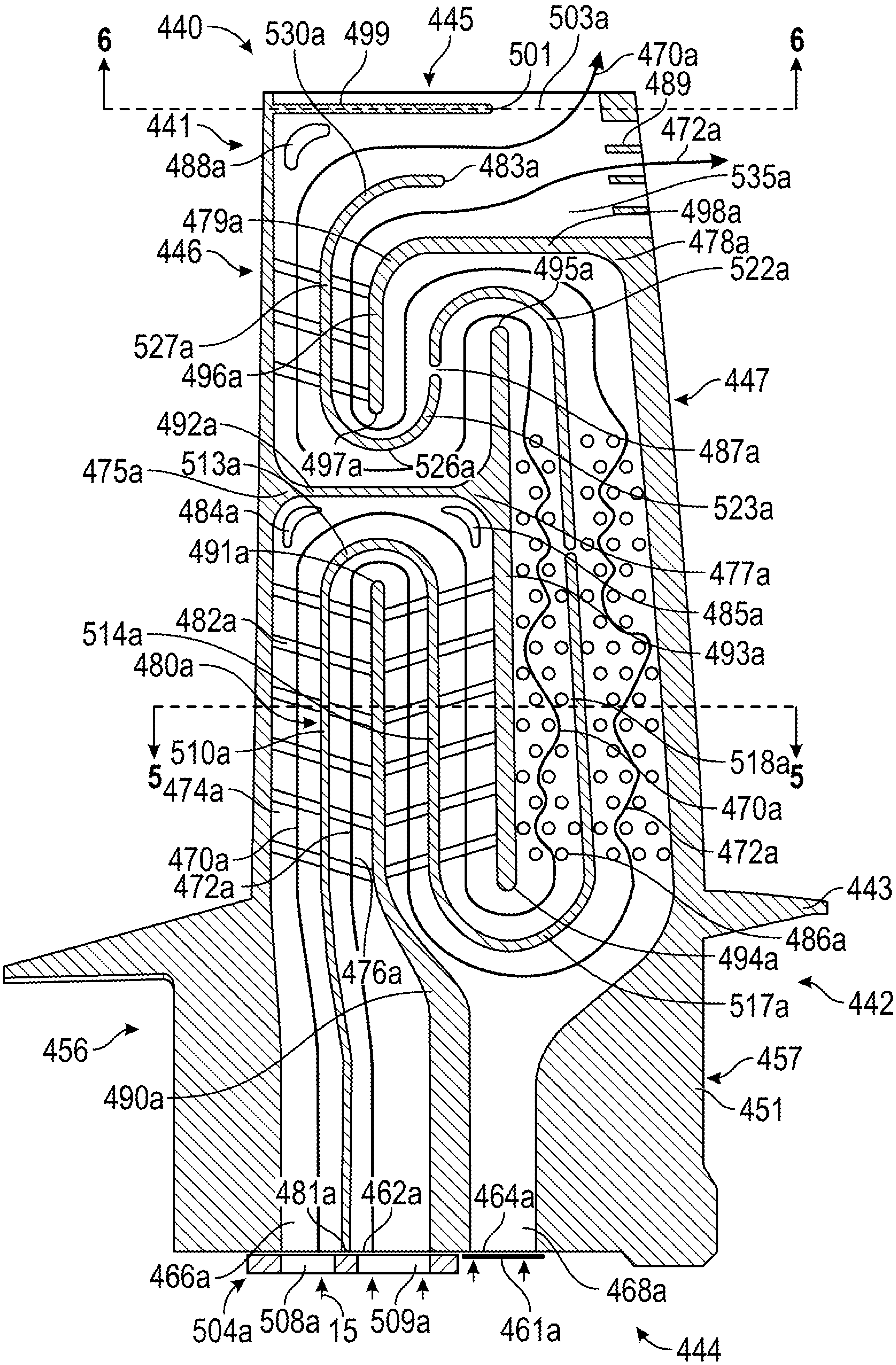
96
445
460
449
450
448
447
507
441
506
446
443
442
451
456
444

FIG. 3


6
440
530a
499
445
503a
501
470a
489
6
441
472a
488a
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535a
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478a
446
495a
522a
527a
447
496a
487a
492a
497a
526a
513a
475a
523a
484a
491a
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482a
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493a
480a
510a
518a
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474a
470a
472a
470a
472a
443
476a
486a
494a
442
517a
456
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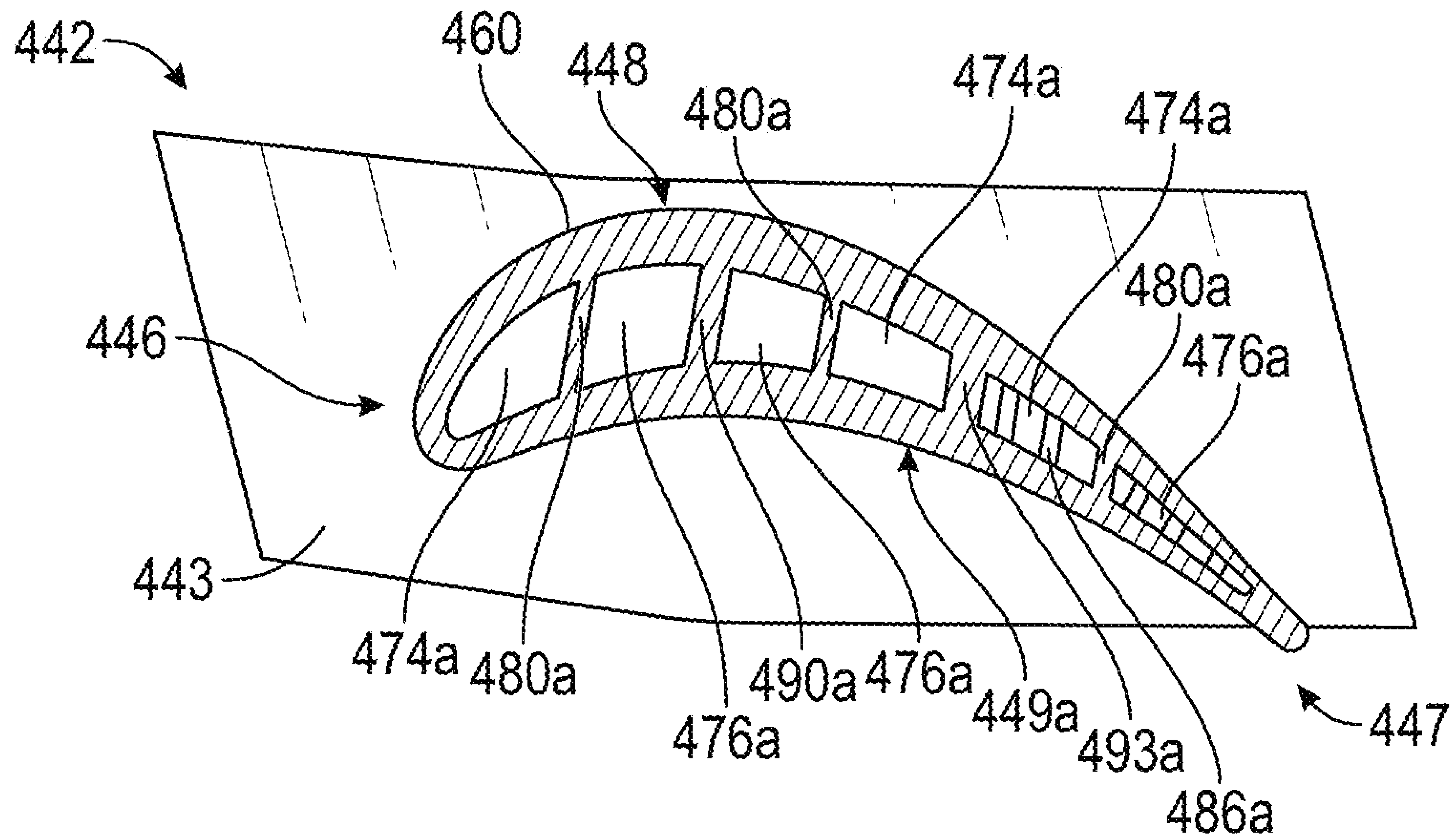
481a
462a
464a
466a
468a
504a
508a
15
509a
461a
444

FIG. 4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460
448
480a
474a
474a
446
480a
476a
443
474a
480a
476a
490a
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449a
493a
486a
447

FIG. 5

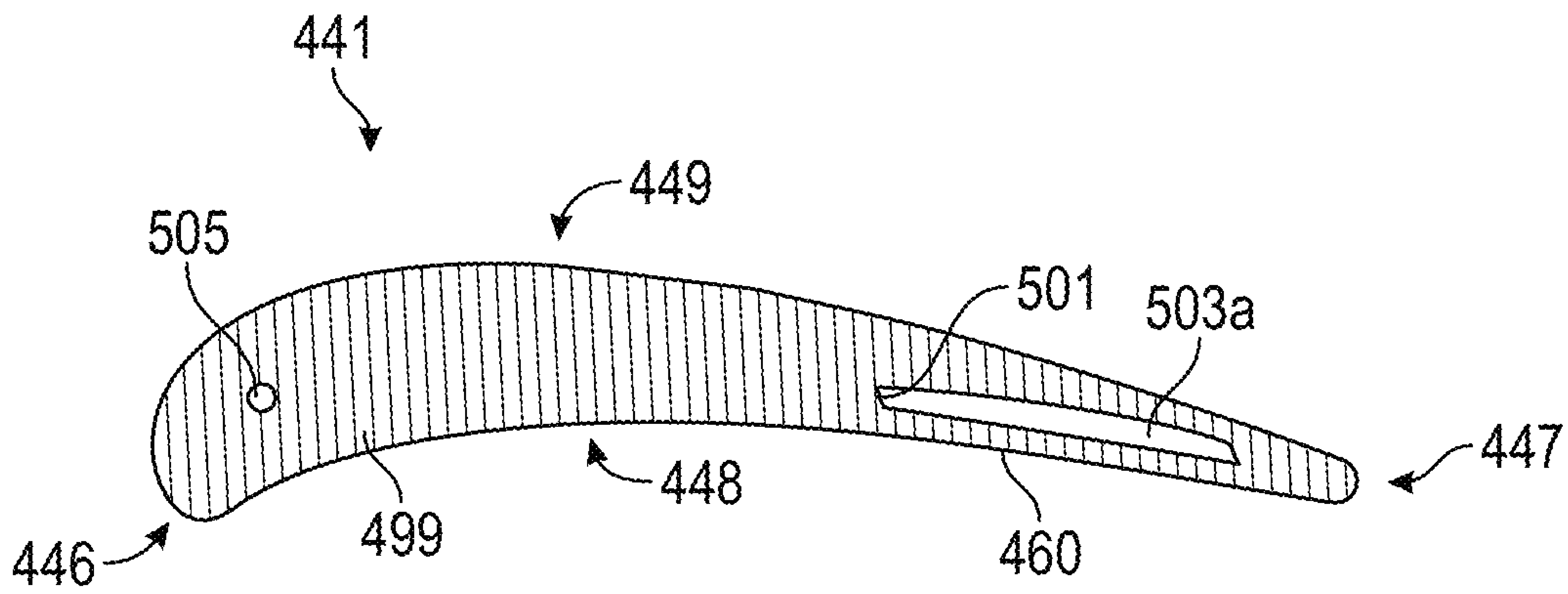
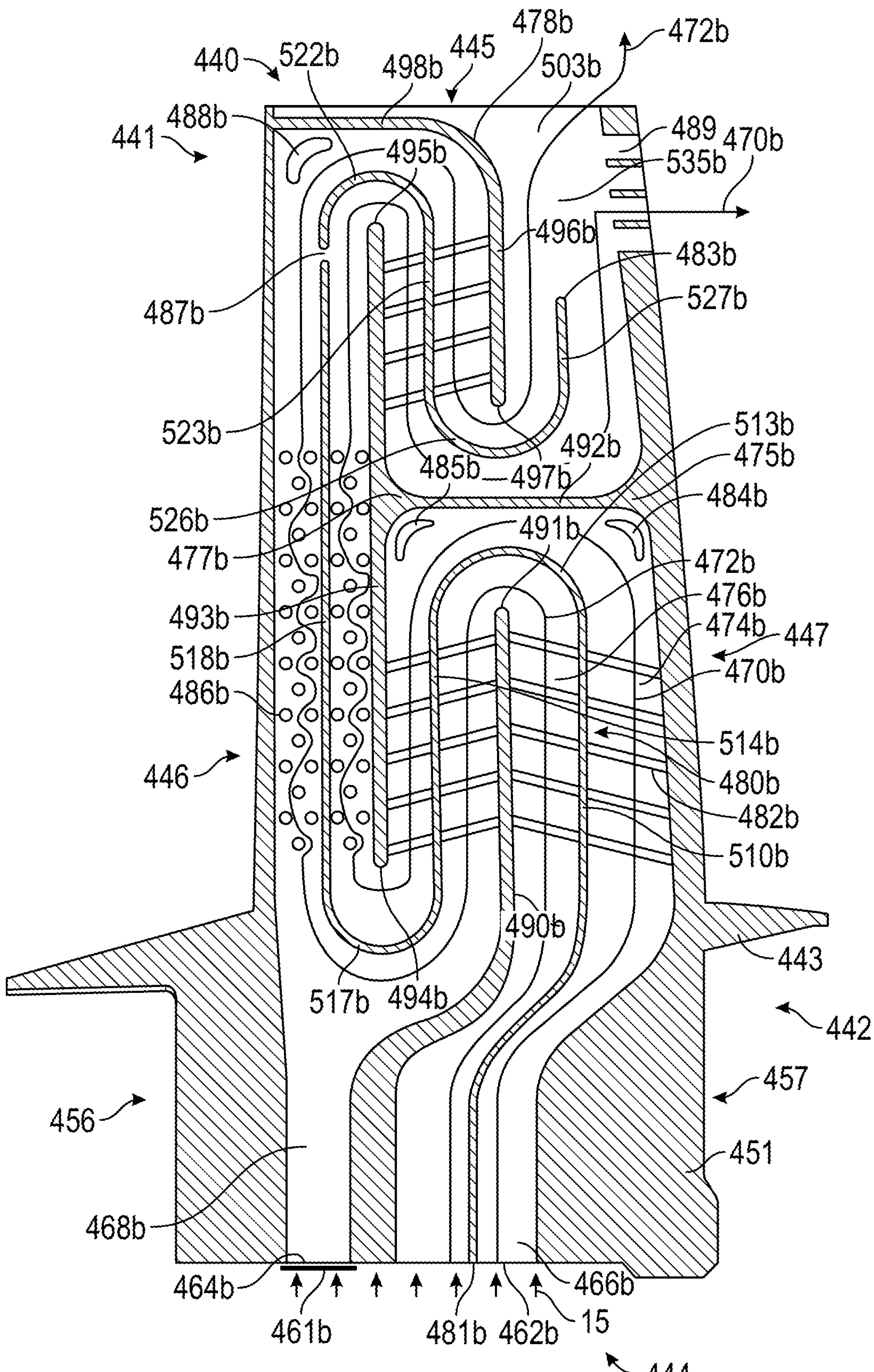

441
449
505
501
503a
447
446
499
448
460

FIG. 6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441
522b
498b
445
478b
472b
503b
488b
489
470b
495b
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523b
513b
492b
475b
485b
497b
484b
526b
477b
491b
472b
493b
476b
474b
447
518b
470b
486b
514b
446
480b
482b
510b
490b
443
517b
494b
442
457
456
451
468b
464b
466b
461b
481b
462b
15
444

FIG. 7

TURBINE BLADE WITH A COUPLED SERPENTINE CHANNEL

TECHNICAL FIELD

The present disclosure generally pertains to gas turbine engines. More particularly this application is directed toward a turbine blade with a coupled serpentine channel.

BACKGROUND

Internally cooled turbine blades may include passages within the blade. These hollow blades may be cast. In casting hollow gas turbine engine blades having internal cooling passageways, a fired ceramic core is positioned in a ceramic investment shell mold to form internal cooling passageways in the cast airfoil. The fired ceramic core used in investment casting of hollow airfoils typically has an airfoil-shaped region with a thin cross-section leading edge region and trailing edge region. Between the leading and trailing edge regions, the core may include elongated and other shaped openings so as to form multiple internal walls, pedestals, turbulators, ribs, and similar features separating and/or residing in cooling passageways in the cast airfoil.

U.S. Pat. No. 8,118,553 to George Liang, describes a cooling system for a turbine airfoil of a turbine engine having dual serpentine cooling channels, an inward serpentine cooling channel and an outward serpentine cooling channel, positioned within the airfoil. The inward serpentine cooling channel may receive cooling fluids from a cooling supply system through the root and exhaust cooling fluids to the outward serpentine cooling channel at the leading edge. The outward serpentine cooling channel may pass the cooling fluids through the outward portion of the serpentine cooling channel and exhaust the cooling fluids through the trailing edge of the airfoil. Such configuration yields a better creep capability for the blade.

The present disclosure is directed toward overcoming one or more of the problems discovered by the inventors.

SUMMARY

A turbine blade for a gas turbine engine is disclosed herein. In embodiments the turbine blade includes a base and an airfoil. The base includes a root end and the airfoil includes a skin extending from the base and defining a first edge, a second edge opposite the first edge, a pressure side, and a lift side opposite the pressure side, and having a tip end opposite from the root end.

The airfoil further includes a base rib, a center divider, a center rib, a tip center rib, a tip rib, a tip wall, and a dividing rib. The base rib disposed within the airfoil and the base, extending from the base and into the airfoil, and having a base rib end disposed opposite from the base. The center divider extending from adjacent the first edge towards the second edge, disposed between the base rib and the tip end. The center rib disposed between the center divider and the second edge, extending from adjacent the center divider towards the tip end and extending from adjacent the center divider towards the root end, the center rib disposed between the root end and the tip end and at least partially between the base rib and the second edge. The center rib having a center rib tip end disposed at the tip end of the center rib, and a center rib base end disposed opposite from the tip end. The tip center rib extending from adjacent the second edge towards the first edge, disposed between the center rib and the tip end. The tip rib extending from adjacent the tip center rib, distal to the second edge, towards the base, the tip rib disposed at least partially between the center rib and the first edge, disposed between the center divider and the tip end, and having a tip rib end disposed opposite from the tip end. The dividing rib extending from a dividing rib base end proximate an interface of the airfoil and the base, towards the tip end while between the first edge and the base rib, to between the tip rib and the first edge and between the tip end and the center divider. The dividing rib having a dividing rib tip end disposed proximate and spaced from the tip end.

The turbine blade further includes a first channel beginning between the dividing rib base end and the first edge. The first channel extending to the center divider while between the first edge and the dividing rib. The first channel further extends around the base rib tip, between the dividing rib and the center divider, and further to between the dividing rib and the center rib. The first channel further extends toward the root end while located between the dividing rib and the center rib. The first channel further extends around the center rib base end while between the center rib and the dividing rib, towards the tip end while between the center rib and the dividing rib. The first channel further extends towards the tip end while between the center rib and the dividing rib. The first channel further extends around the center rib tip end while between the center rib and dividing rib, towards the base while between the dividing rib and the center rib. The first channel further extends to the center divider while between the dividing rib and center rib. The first channel further extends around the tip rib end while between the dividing rib and the center divider, to between the dividing rib and the first edge. The first channel further extends towards the tip end, between the first edge and the dividing rib, to between the dividing rib and the tip wall.

BRIEF DESCRIPTION OF THE FIGURES

The details of embodiments of the present disclosure, both as to their structure and operation, may be gleaned in part by study of the accompanying drawings, in which like reference numerals refer to like parts, and in which:

FIG. **1** is a schematic illustration of an exemplary gas turbine engine;

FIG. **2** is an axial view of an exemplary turbine rotor assembly;

FIG. **3** is an isometric view of one turbine blade of FIG. **2**;

FIG. **4** is a cutaway side view of the turbine blade of FIG. **3**;

FIG. **5** is a cross section of the cooled turbine blade taken along the line **5-5** of FIG. **4**;

FIG. **6** is a cross section of the cooled turbine blade taken along the line **6-6** of FIG. **4**; and

FIG. **7** is a cutaway side view of an another embodiment of the turbine blade of FIG. **3**;

DETAILED DESCRIPTION

The detailed description set forth below, in connection with the accompanying drawings, is intended as a description of various embodiments and is not intended to represent the only embodiments in which the disclosure may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of the embodiments. However, it will be apparent to those skilled in the art that the disclosure without these specific details. In some instances, well-known structures and components are shown in simplified form for brevity of description.

FIG. **1** is a schematic illustration of an exemplary gas turbine engine. Some of the surfaces have been left out or exaggerated for clarity and ease of explanation. Also, the disclosure may reference a forward and an aft direction. Generally, all references to "forward" and "aft" are associated with the flow direction of primary air (i.e., air used in the combustion process), unless specified otherwise. For example, forward is "upstream" relative to primary air flow, and aft is "downstream" relative to primary air flow.

In addition, the disclosure may generally reference a center axis **95** of rotation of the gas turbine engine, which may be generally defined by the longitudinal axis of its shaft **120** (supported by a plurality of bearing assemblies **150**). The center axis **95** may be common to or shared with various other engine concentric components. All references to radial, axial, and circumferential directions and measures refer to center axis **95**, unless specified otherwise, and terms such as "inner" and "outer" generally indicate a lesser or greater radial distance from, wherein a radial **96** may be in any direction perpendicular and radiating outward from center axis **95**.

A gas turbine engine **100** includes an inlet **110**, a gas producer or "compressor" **200**, a combustor **300**, a turbine **400**, an exhaust **500**, and a power output coupling **50**. The compressor **200** includes one or more compressor rotor assemblies **220**. The combustor **300** includes one or more injectors **350** and includes one or more combustion chambers **390**. The turbine **400** includes one or more turbine rotor assemblies **420**. The exhaust **500** includes an exhaust diffuser **520** and an exhaust collector **550**.

As illustrated, both compressor rotor assembly **220** and turbine rotor assembly **420** are axial flow rotor assemblies, where each rotor assembly includes a rotor disk that is circumferentially populated with a plurality of airfoils ("rotor blades"). When installed, the rotor blades associated with one rotor disk are axially separated from the rotor blades associated with an adjacent disk by stationary vanes ("stator vanes" or "stators") circumferentially distributed in an annular casing.

A gas (typically air **10**) enters the inlet **110** as a "working fluid", and is compressed by the compressor **200**. In the compressor **200**, the working fluid is compressed in an annular flow path **115** by the series of compressor rotor assemblies **220**. In particular, the air **10** is compressed in numbered "stages", the stages being associated with each compressor rotor assembly **220**. For example, "4th stage air" may be associated with the 4th compressor rotor assembly **220** in the downstream or "aft" direction—going from the inlet **110** towards the exhaust **500**). Likewise, each turbine rotor assembly **420** may be associated with a numbered stage. For example, first stage turbine rotor assembly **421** is the forward most of the turbine rotor assemblies **420**. However, other numbering/naming conventions may also be used.

Once compressed air **10** leaves the compressor **200**, it enters the combustor **300**, where it is diffused and fuel **20** is added. Air **10** and fuel **20** are injected into the combustion chamber **390** via injector **350** and ignited. After the combustion reaction, energy is then extracted from the combusted fuel/air mixture via the turbine **400** by each stage of the series of turbine rotor assemblies **420**. Exhaust gas **90** may then be diffused in exhaust diffuser **520** and collected, redirected, and exit the system via an exhaust collector **550**. Exhaust gas **90** may also be further processed (e.g., to reduce harmful emissions, and/or to recover heat from the exhaust gas **90**).

One or more of the above components (or their subcomponents) may be made from stainless steel and/or durable, high temperature materials known as "superalloys". A superalloy, or high-performance alloy, is an alloy that exhibits excellent mechanical strength and creep resistance at high temperatures, good surface stability, and corrosion and oxidation resistance. Superalloys may include materials such as HASTELLOY, INCONEL, WASPALOY, RENE alloys, HAYNES alloys, INCOLOY, MP98T, TMS alloys, and CMSX single crystal alloys.

FIG. **2** is an axial view of an exemplary turbine rotor assembly. In particular, the turbine rotor assembly **420** schematically illustrated in FIG. **1** is shown here in greater detail, but in isolation from the rest of gas turbine engine **100**. The turbine rotor assembly **420** includes a turbine rotor disk **430** that is circumferentially populated with a plurality of turbine blades configured to receive cooling air ("cooled turbine blades" **440**) and a plurality of dampers **426**. Here, for illustration purposes, turbine rotor disk **430** is shown depopulated of all but three cooled turbine blades **440** and three dampers **426**.

Each cooled turbine blade **440** may include a base **442** including a platform **443** and a blade root **451**. For example, the blade root **451** may incorporate "fir tree", "bulb", or "dove tail" roots, to list a few. Correspondingly, the turbine rotor disk **430** may include a plurality of circumferentially distributed slots or "blade attachment grooves" **432** configured to receive and retain each cooled turbine blade **440**. In particular, the blade attachment grooves **432** may be configured to mate with the blade root **451**, both having a reciprocal shape with each other. In addition the blade attachment grooves **432** may be slideably engaged with the blade attachment grooves **432**, for example, in a forward-to-aft direction.

Being proximate the combustor **300** (FIG. **1**), the turbine rotor assembly **420** may incorporate active cooling. In particular, compressed cooling air may be internally supplied to each cooled turbine blade **440** as well as predetermined portions of the turbine rotor disk **430**. For example, here turbine rotor disk **430** engages the cooled turbine blade **440** such that a cooling air cavity **433** is formed between the blade attachment grooves **432** and the blade root **451**. In other embodiments, other stages of the turbine may incorporate active cooling as well.

When a pair of cooled turbine blades **440** is mounted in adjacent blade attachment grooves **432** of turbine rotor disk **430**, an under-platform cavity may be formed above the circumferential outer edge of turbine rotor disk **430**, between shanks of adjacent blade roots **451**, and below their adjacent platforms **443**, respectively. As such, each damper **426** may be configured to fit this under-platform cavity. Alternately, where the platforms are flush with circumferential outer edge of turbine rotor disk **430**, and/or the under-platform cavity is sufficiently small, the damper **426** may be omitted entirely.

Here, as illustrated, each damper **426** may be configured to constrain received cooling air such that a positive pressure may be created within the under-platform cavity to suppress the ingress of hot gases from the turbine. Additionally, damper **426** may be further configured to regulate the flow of cooling air to components downstream of the turbine rotor assembly **420**. For example, damper **426** may include one or more aft plate apertures in its aft face. Certain features of the illustration may be simplified and/or differ from a production part for clarity.

Each damper **426** may be configured to be assembled with the turbine rotor disk **430** during assembly of the turbine rotor assembly **420**, for example, by a press fit. In addition, the damper **426** may form at least a partial seal with the adjacent cooled turbine blades **440**. Furthermore, one or more axial faces of damper **426** may be sized to provide sufficient clearance to permit each cooled turbine blade **440** to slide into the blade attachment grooves **432**, past the damper **426** without interference after installation of the damper **426**.

FIG. **3** is a perspective view of the turbine blade of FIG. **2**. As described above, the cooled turbine blade **440** may include a base **442** having a platform **443**, a blade root **451**, and a root end **444**. Each cooled turbine blade **440** may further include an airfoil **441** extending radially outward from the platform **443**. The airfoil **441** may have a complex, geometry that varies radially. For example the cross section of the airfoil **441** may lengthen, thicken, twist, and/or change shape as it radially approaches the platform **443** inward from a tip end **445**. The overall shape of airfoil **441** may also vary from application to application.

The cooled turbine blade **440** is generally described herein with reference to its installation and operation. In particular, the cooled turbine blade **440** is described with reference to both a radial **96** of center axis **95** (FIG. **1**) and the aerodynamic features of the airfoil **441**. The aerodynamic features of the airfoil **441** include a leading edge **446**, a trailing edge **447**, a pressure side **448**, a lift side **449**, and its mean camber line **450**. The leading edge **446** and the trailing edge **447**, either one of which can be referred to a first edge or a second edge. The leading edge **446** may have leading edge holes **506** and trailing edge **447** may have trailing edge slots **507** that can permit cooling air **15** to exit the turbine blade **440**. The mean camber line **450** is generally defined as the line running along the center of the airfoil from the leading edge **446** to the trailing edge **447**. It can be thought of as the average of the pressure side **448** and lift side **449** of the airfoil **441** shape. As discussed above, airfoil **441** also extends radially between the platform **443** and the tip end **445**. Accordingly, the mean camber line **450** herein includes the entire camber sheet continuing from the platform **443** to the tip end **445**.

Thus, when describing the cooled turbine blade **440** as a unit, the inward direction is generally radially inward toward the center axis **95** (FIG. **1**), with its associated end called a "root end" **444**. Likewise the outward direction is generally radially outward from the center axis **95** (FIG. **1**), with its associated end called the "tip end" **445**. When describing the platform **443**, the forward face **456** and the aft face **457** of the platform **443** is associated to the forward and aft axial directions of the center axis **95** (FIG. **1**), as described above. The base **442** can further include a forward face **456** and an aft face **457**. The forward face **456** corresponds to the face of the base **442** that is disposed on the forward end of the base **442**. The aft face **457** corresponds to the face of the base **442** that is disposed distal from the forward face **456**.

In addition, when describing the airfoil **441**, the forward and aft directions are generally measured between its leading edge **446** (forward) and its trailing edge **447** (*aft*), along the mean camber line **450** (artificially treating the mean camber line **450** as linear). When describing the flow features of the airfoil **441**, the inward and outward directions are generally measured in the radial direction relative to the center axis **95** (FIG. **1**). However, when describing the thermodynamic features of the airfoil **441** the inward and outward directions are generally measured in a plane perpendicular to a radial **96** of center axis **95** (FIG. **1**) with inward being toward the mean camber line **450** and outward being toward the "skin" **460** of the airfoil **441**.

Finally, certain traditional aerodynamics terms may be used from time to time herein for clarity, but without being limiting. For example, while it will be discussed that the airfoil **441** (along with the entire cooled turbine blade **440**) may be made as a single metal casting, the outer surface of the airfoil **441** (along with its thickness) is descriptively called herein the "skin" **460** of the airfoil **441**. In another example, each of the ribs described herein can act as a wall or a divider.

FIG. **4** is a cutaway side view of the turbine blade of FIG. **3**. In particular, the cooled turbine blade **440** of FIG. **3** is shown here with the skin **460** removed from the pressure side **448** of the airfoil **441**, exposing its internal structure and cooling paths. The airfoil **441** may include a composite flow path made up of multiple subdivisions and cooling structures. Similarly, a section of the base **442** has been removed to expose portions of a main inlet passage **466***a* and a secondary inlet passage **468***a* internal to the base **442**. The turbine blade **440** shown in FIG. **4** generally depicts the features visible from the pressure side **448**. The leading edge holes **506** and the trailing edge slots **507** have not been shown in FIG. **4**.

The cooled turbine blade **440** includes an airfoil **441** and a base **442**. The base **442** may include the platform **443**, the blade root **451**, the forward face **456**, the aft face **457**, the root end **444**, a main inlet **462***a*, and a secondary inlet **464***a*. The airfoil **441** interfaces with the base **442** and may include the skin **460**, a tip wall **499**, a dividing rib **480***a*, a tip opening **503***a*, and a trailing edge outlet **489***a*.

Compressed secondary air **15** may be routed into the main inlet **462***a* and secondary inlet **464***a* in the base **442** of cooled turbine blade **440** as cooling air **15**. The main inlet **462***a* and secondary inlet **464***a* may be at any convenient location. For example, here, the main inlet **462***a* and secondary inlet **464***a* are located in the blade root **451**. Alternately, cooling air **15** may be received in a shank area radially outward from the blade root **451** but radially inward from the platform **443**. The main inlet **462***a* may be disposed between the forward face **456** and the secondary inlet **464***a*. The main inlet **462***a* is configured to allow compressed cooling air **15** into the turbine blade **440**. The secondary inlet may be disposed between the main inlet **462***a* and the aft face **457**. In an embodiment, a blocking plate **461***a* may be disposed radially inward of the secondary inlet **464***a* and can restrict the cooling air **15** from entering the secondary inlet **464***a*. In some embodiments the secondary inlet **464***a* is present to aid in casting the cooled turbine blade **440**.

Within the base **442**, the cooled turbine blade **440** includes the main inlet passage **466***a* configured to route cooling air **15** from the main inlet **462***a*, through the base **442**, and into the airfoil **441** via the first channel **474***a* and the second channel **476***a*. The base **442** may also include a secondary inlet passage **468***a* that is configured to route cooling air **15** from the secondary inlet **464***a*, through the base **442** and into the airfoil **441** via the second channel **476***a*. The main inlet passage **466***a* and secondary inlet passage **468***a* may be configured to translate the cooling air **15** in three dimensions (e.g., not merely in the plane of the figure) as it travels radially up (e.g., generally along a radial **96** of the center axis **95** (FIG. **1**)) towards the airfoil **441** and along a first multi-bend heat exchange path **470***a* and a second multi-bend heat exchange path **472***a*. For example, the cooling air

15 can travel radially and within the airfoil **441**. The first multi-bend heat exchange path **470***a* and the second multi-bend heat exchange path **472***a* are depicted as solid lines drawn as a weaving path through the airfoil **441**, exiting through the airfoil **441** and ending with an arrow. The first multi-bend heat exchange path **470***a* may be an air flow path confined or substantially confined by the first channel **474***a* and the second multi-bend heat exchange path **472***a* may be an air flow path confined or substantially confined by the second channel **476***a*.

Within the skin **460** of the airfoil **441** and the base **442** of the turbine blade, several internal structures are viewable. In particular, the turbine blade **440** includes a base rib **490***a*, a center divider **492***a*, a center rib **493***a*, a tip rib **496***a*, a tip center rib **498***a*, and a dividing rib **480***a*. Several of the internal structures, such as the base rib **490***a*, the center divider **492***a*, the center rib **493***a*, the tip rib **496***a*, the tip center rib **498***a*, and the dividing rib **480***a*, may remain continuous or include gaps. In addition, the airfoil **441** may include a tip wall **499**, turbulators **482***a*, a first edge air deflector **484***a*, a center air deflector **485***a*, a tip air deflector **488***a*, cooling fins **486***a*, a trailing edge outlet **489***a*, and a tip opening **503***a*.

In an embodiment, the base rib **490***a* is disposed within the airfoil **441** and the base **442** and extends from the base **442** and up into the airfoil **441**. In other words, the base rib **490***a* can be disposed between the main inlet passage **466***a* and the secondary inlet passage **468***a* and extend from the root end **444** towards the tip end **445**. The base rib **490***a* can bend towards the leading edge **446** when located proximate to the interface of the airfoil **441** and the base **442**. The base rib **490***a* can extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. The base rib **490***a* may be located between the main inlet **462***a* and the secondary inlet **464***a*. The base rib **490***a* can be wider adjacent the root end **444** than opposite from the root end **444**. The base rib **490***a* may include a base rib end **491***a* disposed opposite from the base **442**. The base rib end **491***a* may be disposed closer to the leading edge **446** than the base rib **490***a* proximate the root end **444**.

In an embodiment, the center divider **492***a* extends from leading edge **446** towards the trailing edge **447**. The center divider **492***a* is disposed between the base rib **490***a* and the tip end **445**. Further, the center divider **492***a* can be disposed between the base rib **490***a* and the tip rib **496***a*. The center divider **492***a* can extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. The center divider **492***a* can have a center divider transition **475***a* that extends from the center divider **492***a* to the leading edge **446** and is wider adjacent the leading edge **446** than opposite the leading edge **446**. The center divider transition **475***a* may be shaped as a double fillet tee joint joining the center divider **492***a* to the leading edge **446**. The center divider **492***a* may have a center rib transition **477***a* that is disposed opposite from the center divider transition **475***a*. The center rib transition **477***a* may extend from the center divider **492***a* to the center rib **493***a* and be wider adjacent the center rib **493***a* than opposite the center rib **493***a*. The center rib transition **477***a* may be shaped as a double fillet tee joint joining the center divider **492***a* to the center rib **493***a*.

The center rib **493***a* is disposed between the center divider **492***a* and the trailing edge **447**. The center rib **493***a* extends from adjacent the center divider **492***a* towards the tip end **445** and extends from adjacent the center divider **492***a* towards the root end **444**. The center rib **493***a* is also disposed between the root end **444** and the tip end **445**. In an embodiment, the center rib **493***a* may be disposed between the base **442** and the tip center rib **498***a* and can adjoin the center rib transition **477***a*. The center rib can extend **493***a* from the center divider **492***a* to proximate to the interface of where the airfoil **441** extends from the base **442**. The center rib **493***a* can extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. The center rib **493***a* may a have a cross-section shaped as an elongated stadium. The center rib **493***a* may include a center rib tip end **495***a* disposed at the tip end **445** of the center rib **493***a* and a center rib base end **494***a* disposed opposite from the tip end **445**.

The tip center rib **498***a* extends from the trailing edge **447** towards the leading edge **446** and is disposed between the center rib **493***a* and the tip end **445**. The tip center rib **498***a* may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. The tip center rib **498***a* can include a tip center rib transition **478***a* that extends from the tip center rib **498***a* to the trailing edge **447** and be wider adjacent to the trailing edge **447** than opposite the trailing edge **447**. The tip center rib transition **478***a* may be shaped as a fillet joining the tip center rib **498***a* to the trailing edge **447**. The tip center rib **498***a* may include a tip rib transition **479***a* that is disposed opposite from the tip center rib transition **478***a* that extends from the tip center rib **498***a* towards the base **442**. The tip rib transition **479***a* may be shaped as a fixed radial transition joining the tip center rib **498***a* to the tip rib **496***a*.

The tip rib **496***a* extends from the tip center rib **498***a* towards the base **442** and is disposed between the center rib **493***a* and the leading edge **446**. The tip rib **496***a* is also disposed between the center divider **492***a* and the tip end **445**. The tip rib **496***a* may extend from the tip rib transition **479***a* towards the base **442**. The tip rib **496***a* may extend from the pressure side **448** of the skin to the lift side **449** of the skin **460**. The tip rib **496***a* may in include a tip rib end **497***a* disposed opposite from the tip end **445**.

The tip wall **499** may extend from the leading edge **446** towards the trailing edge **447** and disposed proximate the tip end **445**. The tip wall **499** may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. The tip wall **499** may be disposed between the tip end **445** and the tip center rib **498***a*. In other words the tip wall **499** may be disposed between the tip end **445** and the tip rib **496***a*. The tip wall **499** may be recessed inward such that it is not flush with the tip of the airfoil **441**. The tip wall **499** may include a tip wall end **501** disposed opposite from the leading edge **446**.

The tip opening **503***a* is defined by the space between the pressure side **448** of the skin **460**, the lift side **449** of the skin, the tip wall **499**, and the trailing edge **447**. The tip opening **503***a* allows for cooling air **15** to escape the airfoil **441** through the tip end **445**.

The trailing edge outlet **489***a* extends through the trailing edge **447** and is disposed proximate the tip end **445**. The trailing edge outlet **489***a* allows for cooling air **15** to escape the airfoil **441** through the trailing edge **447**.

The dividing rib **480***a* extends throughout the turbine blade **440** in a serpentine configuration. The dividing rib **480***a* can extend from adjacent the main inlet **462***a* to between the leading edge **446** and the base rib **490***a*. In an alternative embodiment the dividing rib **480***a* can extend from proximate to the interface of the airfoil **441** and the base **442**, to between the leading edge **446** and the base rib **490***a*, and further to between the leading edge **446** and tip rib **496***a*. In other words the dividing rib can extend from proximate the base **442**. The dividing rib **480***a* may have several portions including a dividing rib lower first edge portion **510***a*, a dividing rib lower first edge transition portion **513***a*, a dividing rib lower middle portion **514***a*, a dividing rib lower middle transition portion **517***a*, a dividing rib second edge portion **518***a*, a dividing rib second edge transition portion **522***a*, a dividing rib upper middle portion **523***a*, a dividing rib upper middle transition portion **526***a*, a dividing rib upper first edge portion **527***a*, and a dividing rib upper first edge transition portion **530***a*. The dividing rib **480***a* may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. In an embodiment, the dividing rib **480***a* may have dividing rib gaps **487***a* disposed along the dividing rib **480***a*. Alternatively, the dividing rib **480***a* may remain continuous. The dividing rib **480***a* may also include a dividing rib tip end **483***a* disposed proximate and spaced from the tip end **445**.

The dividing rib **480***a* may include a dividing rib base end **481***a* disposed opposite from the dividing rib tip end **483***a*. The dividing rib base end **481***a* can be disposed proximate and spaced from the leading edge **446**, proximate to where the base **442** and airfoil **441** meet. The dividing rib **480***a* can be configured to divide the cooling air **15** into a first channel **474***a* and a second channel **476***a*. The airfoil **441** may include a tip end channel **535** that may begin proximate to the dividing rib tip end **483***a* and where the first channel **474***a* and the second channel **476***a* combine. The tip end channel **535** may be defined by the dividing rib tip end **483***a*, the tip center rib **498***a*, trailing edge **447**, tip wall **499**, the pressure side **448** of the skin **460**, and the lift side **449** of the skin **460**.

In an embodiment, the dividing rib lower first edge portion **510***a* can extend from adjacent the main inlet **462***a* and root end towards the tip end **445** while between the leading edge **446** and the base rib **490***a*. In an alternative embodiment, the dividing rib lower first edge portion **510***a* can extend from proximate to the interface of the airfoil **441** and the base **442** towards the tip end **445** while between the leading edge **446** and the base rib **490***a*. In other words, the dividing rib lower first edge portion **510***a* can extend from proximate the base **442** towards the center divider **492***a*. In other words, the dividing rib lower middle portion **514***a* can extend from proximate to the interface of the airfoil **441** and the base **442** to proximate the base rib end **491***a*.

The dividing rib lower first edge transition portion **513***a* can extend from the dividing rib lower first edge portion **510***a*, from between the leading edge **446** and the base rib **490***a*, around the base rib end **491***a*, to between the base rib **490***a* and the center divider **492***a*, and further to between the base rib **490***a* and the center rib **493***a*. The dividing rib lower first edge transition portion **513***a* may have a cross-section shaped as an annulus sector.

The dividing rib lower middle portion **514***a* can extend from the dividing rib lower first edge transition portion **513***a* towards the root end **444** while located between the base rib **490***a* and the center rib **493***a*. In other words, the dividing rib lower middle portion **514***a* can extend from proximate the base rib end **491***a* to proximate the center rib base end **494***a*. The dividing rib lower middle portion is disposed between the center divider **492***a* and the root end **444**.

The dividing rib lower middle transition portion **517***a* can extend from the dividing rib lower middle portion **514***a*, from between the base rib **490***a* and the center rib **493***a*, around the center rib **493***a* base end **494***a*, to between the center rib **493***a* and the base rib **490***a*, and further to between the center rib **493***a* and the trailing edge **447**. The dividing rib lower middle transition portion **517***a* may have a cross-section shaped as an annulus sector.

The dividing rib second edge portion **518***a* can extend from the dividing rib lower middle transition portion **517***a* towards the tip end **445** while between the center rib **493***a* and the trailing edge **447**. In other words, the dividing rib second edge portion **518***a* can extend from proximate the center rib base end **494***a* to proximate the center rib tip end **495***a*. The dividing rib second edge portion **518***a* is disposed between the root end **444** and the tip center rib **498***a*.

The dividing rib second edge transition portion **522***a* can extend from the dividing rib second edge portion **518***a*, from between the trailing edge **447** and the center rib **493***a*, around the center rib tip end **495***a*, to between the center rib **493***a* and the tip center rib **498***a*, and further to between the tip rib **496***a* and the center rib **493***a*. The dividing rib second edge transition portion **522***a* may have a cross-section shaped as an annulus sector.

The dividing rib upper middle portion **523***a* can extend from the dividing rib second edge transition portion **522***a* towards the center divider **492***a* while between the tip rib **496***a* and center rib **493***a*. In other words, the dividing rib upper middle portion **523***a* can extend from proximate the center rib tip end **495***a* to proximate the tip rib end **497***a*. The dividing rib upper middle portion **523***a* is disposed between the tip end **445** and the center divider **492***a*.

The dividing rib upper middle transition portion **526***a* can extend from the dividing rib upper middle portion **523***a*, from between the tip rib **496***a* and the center rib **493***a*, around the tip rib end **497***a*, to between the tip rib **496***a* and the center divider **492***a*, and further to between the tip rib **496***a* and the leading edge **446**. The dividing rib upper middle transition portion **526***a* may have a cross-section shaped as an annulus sector.

The dividing rib upper first edge portion **527***a* can extend from the dividing rib upper middle transition portion **526***a* towards the tip end **445**, between the leading edge **446** and the tip rib **496***a*. In other words, the dividing rib upper first edge portion **527***a* can extend from proximate the tip rib end **497***a* towards the tip wall **499**. The dividing rib upper first edge portion **527***a* is disposed between the center divider **492***a* and tip wall **499**.

The dividing rib upper first edge transition portion **530***a* can extend from the dividing rib upper first edge portion **527***a* towards the tip end **445**, from between the leading edge **446** and tip rib **496***a*, around the tip rib transition **479***a*, to between the tip end **445** and the tip center rib **498***a*. Together with the skin **460**, the dividing rib **480***a* and other described structures, may form the first channel **474***a* and first multi-bend heat exchange path **470***a* along with the second channel **476** the second multi-bend heat exchange path **472***a* within the airfoil **441**.

The first channel **474***a* may extend throughout the turbine blade **440** in a serpentine configuration similar to and partially defined by the dividing rib **480***a* and can be formed by the dividing rib **480***a*, the skin **460**, and other internal structures in the airfoil **441**. The first channel **474***a* can be in flow communication with the main inlet passage **466***a* and main inlet **462***a*. The first channel **474***a* can begin between the forward face **456** and the dividing rib **480***a* and disposed adjacent the main inlet **462***a*. Alternatively, the first channel **474***a* can begin between the dividing rib base end **481***a* and the leading edge **446**. The first channel **474***a* can extend to the center divider **492***a* while between the leading edge **446** and the dividing rib **480***a*. The first channel **474***a* can continue extending around the base rib end **491***a*, between the dividing rib **480***a* and the center divider **492***a*, and further to between the dividing rib **480***a* and the center rib **493***a*. The first channel **474***a* can then extend toward the root end **444** while located between the dividing rib **480***a* and the center rib **493***a*. The first channel **474***a* can further extend around the center rib base end **494***a* while between the center rib **493***a* and the dividing rib **480***a*, and towards the tip end **445** while between the center rib **493***a* and the dividing rib **480***a*. The first channel **474***a* can continue by extending towards the tip end **445** while between the center rib **493***a* and the dividing rib **480***a*. The first channel **474***a* can further continue by extending around the center rib tip end **495***a* while between the center rib **493***a* and dividing rib **480***a*, towards the base **442** while between the dividing rib **480***a* and the center rib **493***a*. The first channel **474***a* can continue by extending to the center divider **492***a* while between the dividing rib and center rib **493***a*. The first channel **474***a* can continue by extending around the tip rib end **497***a* while between the dividing rib and the center divider **492***a*, to between the dividing rib **480***a* and the leading edge **446**. The first channel **474***a* can further continue by extending towards the tip end **445**, between the leading edge **446** and the dividing rib **480***a*, to between the dividing rib **480***a* and the tip wall **499**, and further to the tip end channel **535**.

The second channel **476***a* may extend throughout the turbine blade **440** in a serpentine configuration similar to the first channel **474***a* and can be formed by the dividing rib **480***a*, the skin **460**, and other internal structures in the airfoil **441**. The second channel **476***a* may be in flow communication with the main inlet **462***a* and the main inlet passage **466***a*. The second channel **476***a* may be in flow communication with the secondary inlet **464***a* and the secondary inlet passage **468***a*. The second channel **476***a* can begin between the dividing rib **480***a* and the base rib **490***a* and disposed adjacent the main inlet **462***a*. Alternatively, the second channel **476***a* can begin between the dividing rib base end **481***a* and the base rib **490***a*. The second channel **476***a* can extend from between the dividing rib **480***a* and the base rib **490***a* to the center divider **492***a*. The second channel **476***a* can continue extending around the base rib end **491***a*, to between the base rib **490***a* and the dividing rib **480***a*, and further towards the base **442**. The second channel **476***a* can then extend further towards the root end **444**, while located between the base rib **490***a* and the dividing rib **480***a*. The second channel **476***a* can further extend around the center rib base end **494***a* between the dividing rib **480***a* and the root end **444**, to between the dividing rib **480***a* and the trailing edge **447**. The second channel **476***a* can continue by extending to the tip center rib **498***a* while between the dividing rib **480***a* and the trailing edge **447**. The second channel **476***a* can further continue by extending around the center rib tip end **495***a* while between the dividing rib **480***a* and the tip center rib **498***a*, to between the tip rib **496***a* and the dividing rib **480***a*. The second channel **476***a* can continue by extending towards the center divider **492***a* while between the tip rib **496***a* and dividing rib **480***a*. The second channel **476***a* can continue by extending around the tip rib end **497***a* while between the tip rib **496***a* and the dividing rib **480***a*, towards the tip end **445**. The second channel **476***a* can further continue by extending towards the tip end **445**, between the dividing rib **480***a* and the tip rib **496***a*, to the tip end channel **535**.

The internal structures making up the first multi-bend heat exchange path **470***a* and second multi-bend heat exchange path **472***a* may form multiple discrete sub-passageways. For example, although the first multi-bend heat exchange path **470***a* and the second multi-bend heat exchange path **472***a* are shown by a representative path of cooling air **15**, multiple composite flow paths are possible.

The possible multiple composite flow paths may include additional features within the airfoil **441**. These features may be turbulators **482***a*, cooling fins **486***a*, a first edge air deflector **484***a*, a center air deflector **485***a*, and a tip air deflector **488***a*.

In an embodiment, the turbulators **482***a* may be disposed between the leading edge **446** and the dividing rib **480***a* and between the dividing rib **480***a* and the base rib **490***a*. The turbulators **482***a* can be distributed throughout the other remaining areas of the airfoil **441** as well. The turbulators **482***a* can be formed as ridges on the skin **460** and can be operable to interrupt flow along the first channel **474***a* and second channel **476***a* and prevent formation of a boundary layer which can decrease cooling effects of the cooling air **15**.

The cooling fins **486***a* may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. In an embodiment the cooling fins are disposed between the center rib **493***a* and the trailing edge **447**. The cooling fins **486***a* may be disbursed copiously throughout the airfoil **441** or in other selected locations. In particular, the cooling fins **486***a* may be disbursed throughout the airfoil **441** so as to thermally interact with the cooling air **15** for increased cooling. The distribution may be regular, irregular, staggered, and/or localized. According to one embodiment, one or more of the cooling fins **486***a* may be pin fins or pedestals. The pin fins or pedestals may include many different cross-sectional areas, such as: circular, oval, racetrack, square, rectangular, diamond cross-sections, just to mention only a few. As discussed above, the pin fins or pedestals may be arranged as a staggered array, a linear array, or an irregular array.

The airfoil **441** may include several air deflectors including a first edge air deflector **484***a*, a center air deflector **485***a*, and a tip air deflector **488***a* that may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin. The first edge air deflector **484***a*, center air deflector **485***a*, and tip air deflector **488***a* can also have an aerodynamic shape having a chord length to width ratio of approximately 2:1 to 3:1 ratio. The first edge air deflector **484***a* can be disposed proximate to the center divider **492***a* and the leading edge **446**. In other words, the first edge air deflector **484***a* can be disposed proximate to the center divider transition **475***a*. The center air deflector **485***a* can be disposed proximate to the center divider **492***a* and the center rib **493***a*. In other words, the center air deflector **485***a* can be disposed proximate to the center rib transition **477***a*. The tip air deflector **488***a* can be disposed proximate to the leading edge **446** and the tip wall **499**. The first edge air deflector **484***a*, center air deflector **485***a*, and tip air deflector **488***a* can have sizes and positions selected to maximize cooling in their respective locations. The first edge air deflector **484***a*, center air deflector **485***a*, and tip air deflector **488***a* may be configured to redirect cooling air **15** flowing through the first channel **474***a*. The size, arrangement, shape of the first edge air deflector **484***a*, center air deflector **485***a*, and tip air deflector **488***a* are selected to optimize cooling effectiveness of the cooling air **15** and increase fatigue life of the cooled turbine blade **440**. This can reduce the presence of dead spots, leading to more uniform cooling for the cooled turbine blade **440**.

The turbine blade **440** may further include a metering plate **504***a*. The metering plate **504***a* can be disposed adjacent to and radially inward of the main inlet **462***a* with respect to the central axis **95**. The metering plate **504***a* may extend from the adjacent the base rib **490***a* towards the forward face **456**. The metering plate **504***a* may include a first metering orifice **508***a* and a second metering orifice

509*a*. In an embodiment, the second metering orifice **509***a* is disposed proximate to the dividing rib **480***a* and the base rib **490***a*, and is in flow communication with the second channel **476***a*. The size of the second metering orifice **509***a* can be selected to provide a desired amount or flow of cooling air **15** to the second channel **476***a*. In an embodiment, the first metering orifice **508***a* is disposed between the second metering orifice **509***a* and the forward face **456**. The size of the first metering orifice **509***a* can selected to provide a desired amount or flow of cooling air **15** to the first channel **474***a*.

FIG. **5** is a cross section of the cooled turbine blade taken along the line **5-5** of FIG. **4**. In an embodiment, the airfoil **441** can have a skin **460** that encompasses multiple structural elements. In an embodiment, the first channel **474***a* can be disposed between the leading edge **446** and the dividing rib **480***a*, as well as between the center rib **493***a* and the dividing rib **480***a*. The second channel **476***a* can be disposed between the dividing rib **480***a* and the base rib **490***a*, as well as between the trailing edge **447** and the dividing rib **480***a*.

FIG. **6** is a cross section of the cooled turbine blade taken along the line **6-6** of FIG. **4**. In an embodiment, the airfoil **441** can have a skin **460** that encompasses multiple structural elements. In an embodiment, the tip wall **499** can have a tip end vent **505** that is configured such that a small quantity of the cooling air **15** may be bled off for film cooling near the tip end **445**. The airfoil **441** may also include a tip opening **503***a* that is defined by the space between the pressure side **448** of the skin **460**, the lift side **449** of the skin, the tip wall **499**, and the trailing edge **447**. The tip opening **503***a* operable to allow for cooling air **15** to escape the airfoil **441** near the tip end **445**.

FIG. **7** is a cutaway side view of another embodiment of the turbine blade of FIG. **3**. Structures and features previously described in connection with earlier described embodiments may not be repeated here with the understanding that when appropriate, that previous description applies to the embodiment depicted in FIG. **7**. Additionally, the emphasis in the following description is on variations of previously introduced feature or elements. Also, some reference numbers for previously descripted features are omitted. In particular, another embodiment of the cooled turbine blade **440** of FIG. **3** is shown here with the skin **460** removed from the pressure side **448** of the airfoil **441**, exposing its internal structure and cooling paths. The airfoil **441** may include a composite flow path made up of multiple subdivisions and cooling structures. Similarly, a section of the base **442** has been removed to expose portions of a main inlet passage **466***b* and a secondary inlet passage **468***b* internal to the base **442**. The turbine blade **440** shown in FIG. **7** generally depicts the features visible from the pressure side **448**.

In an embodiment, the base rib **490***b* can bend towards the trailing edge **447** when located proximate to the interface of where the airfoil **441** extends from the base **442**. The base rib end **491***b* may be disposed closer to the trailing edge **447** than the base rib **490***b* proximate the root end **444**.

In an embodiment, the center divider **492***b* extends from trailing edge **447** towards the leading edge **446**. The center divider **492***b* can have a center divider transition **475***b* that extends from the center divider **492***b* to the trailing edge **447** and is wider adjacent the trailing edge **447** than opposite the trailing edge **447**. The center divider transition **475***b* may be shaped as a double fillet tee joint joining the center divider **492***b* to the trailing edge **447**.

The center rib **493***b* is disposed between the center divider **492***b* and the leading edge **446**.

The tip center rib **498***b* extends from the leading edge **446** towards the trailing edge **447** and is disposed between the center rib **493***b* and the tip end **445**. The tip center rib **498***b* can include a tip center rib transition **478***b* that extends from the tip center rib **498***b* to the leading edge **446** and be wider adjacent to the leading edge **446** than opposite the leading edge **446**. The tip center rib transition **478***b* may be shaped as a fillet joining the tip center rib **498***b* to the leading edge **446**.

The tip rib **496***b* extends from the tip center rib **498***b* towards the base **442** and is disposed between the center rib **493***b* and the trailing edge **447**.

The tip opening **503***b* is defined by the space between the pressure side **448** of the skin **460**, the lift side **449** of the skin, the tip center rib **498***b*, and the trailing edge **447**. The tip opening **503***b* allows for cooling air **15** to escape the airfoil **441** through the tip end **445**.

The dividing rib **480***b* extends throughout the turbine blade **440** in a serpentine configuration. The dividing rib **480***b* can extend from adjacent the main inlet **462***b* to between the trailing edge **447** and the base rib **490***b*. In an alternative embodiment the dividing rib **480***b* can extend from proximate to the interface of the airfoil **441** and the base **442**, to between the trailing edge **447** and the base rib **490***b*, and further to between the leading edge **446** and tip rib **496***b*. In other words the dividing rib can extend from proximate the base **442**. The dividing rib **480***b* may have several portions including a dividing rib lower first edge portion **510***b*, a dividing rib lower first edge transition portion **513***b*, a dividing rib lower middle portion **514***b*, a dividing rib lower middle transition portion **517***b*, a dividing rib second edge portion **518***b*, a dividing rib second edge transition portion **522***b*, a dividing rib upper middle portion **523***b*, a dividing rib upper middle transition portion **526***b*, a dividing rib upper first edge portion **527***b*, a dividing rib upper first edge transition portion **530***b*, and a dividing rib tip end portion **531***b*. The dividing rib **480***b* may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. In an embodiment, the dividing rib **480***b* may have dividing rib gaps **487***b* disposed along the dividing rib **480***b*. Alternatively, the dividing rib **480***b* may remain continuous. The dividing rib **480***b* may also include a dividing rib tip end **483***b* disposed proximate and spaced from the tip end **445**.

The dividing rib **480***b* may include a dividing rib base end **481***b* disposed opposite from the dividing rip tip end **485***b*. The dividing rib base end **481***b* can be disposed proximate and spaced from the trailing edge **447**, proximate to where the base **442** and airfoil **441** meet. The dividing rib **480***b* can be configured to divide the cooling air **15** into a first channel **474***b* and a second channel **476***b*. The airfoil **441** may include a tip end channel **535** that may begin proximate to the dividing rib tip end **483***b* and where the first channel **474***b* and the second channel **476***b* combine. The tip end channel **535** may be defined by the dividing rib tip end **483***b*, the tip center rib **498***b*, trailing edge **447**, the tip rib **496***b*, the pressure side **448** of the skin **460**, and the lift side **449** of the skin **460**.

In an embodiment, the dividing rib lower first edge portion **510***b* can extend from adjacent the main inlet **462***b* and the root end **444** towards the tip end **445** while between the trailing edge **447** and the base rib **490***b*. In an alternative embodiment, the dividing rib lower first edge portion **510***b* can extend from proximate to the interface of the airfoil **441** and the base **442** towards the tip end **445** while between the trailing edge **447** and the base rib **490***b*. In other words, the dividing rib lower first edge portion **510***b* can extend from proximate the base **442** towards the center divider **492**_b_. In other words, the dividing rib lower middle portion **514**_b_ can extend from proximate to the interface of the airfoil **441** and the base **442** to proximate the base rib end **491**_b_.

The dividing rib lower first edge transition portion **513**_b_ can extend from the dividing rib lower first edge portion **510**_b_, from between the trailing edge **447** and the base rib **490**_b_, around the base rib end **491**_b_, to between the base rib **490**_b_ and the center divider **492**_b_, and further to between the base rib **490**_b_ and the center rib **493**_b_.

The dividing rib lower middle portion **514**_b_ can extend from the dividing rib lower first edge transition portion **513**_b_ towards the root end **444** while located between the base rib **490**_b_ and the center rib **493**_b_. In other words, the dividing rib lower middle portion **514**_b_ can extend from proximate the base rib end **491**_b_ to proximate the center rib base end **494**_b_. The dividing rib lower middle portion is disposed between the center divider **492**_b_ and the root end **444**.

The dividing rib lower middle transition portion **517**_b_ can extend from the dividing rib lower middle portion **514**_b_, from between the base rib **490**_b_ and the center rib **493**_b_, around the center rib **493**_b_ base end **494**_b_, to between the center rib **493**_b_ and the base rib **490**_b_, and further to between the center rib **493**_b_ and the leading edge **446**.

The dividing rib second edge portion **518**_b_ can extend from the dividing rib lower middle transition portion **517**_b_ towards the tip end **445** while between the center rib **493**_b_ and the leading edge **446**. In other words, the dividing rib second edge portion **518**_b_ can extend from proximate the center rib base end **494**_b_ to proximate the center rib tip end **495**_b_. The dividing rib second edge portion **518**_b_ is disposed between the root end **444** and the tip center rib **498**_b_.

The dividing rib second edge transition portion **522**_b_ can extend from the dividing rib second edge portion **518**_b_, from between the leading edge **446** and the center rib **493**_b_, around the center rib tip end **495**_b_, to between the center rib **493**_b_ and the tip center rib **498**_b_, and further to between the tip rib **496**_b_ and the center rib **493**_b_.

The dividing rib upper middle portion **523**_b_ can extend from the dividing rib second edge transition portion **522**_b_ towards the center divider **492**_b_ while between the tip rib **496**_b_ and center rib **493**_b_. In other words, the dividing rib upper middle portion **523**_b_ can extend from proximate the center rib tip end **495**_b_ to proximate the tip rib end **497**_b_. The dividing rib upper middle portion **523**_b_ is disposed between the tip end **445** and the center divider **492**_b_.

The dividing rib upper middle transition portion **526**_b_ can extend from the dividing rib upper middle portion **523**_b_, from between the tip rib **496**_b_ and the center rib **493**_b_, around the tip rib end **497**_b_, to between the tip rib **496**_b_ and the center divider **492**_b_, and further to between the tip rib **496**_b_ and the leading edge **446**.

The dividing rib upper first edge portion **527**_b_ can extend from the dividing rib upper middle transition portion **526**_b_ towards the tip end **445**, between the trailing edge **447** and the tip rib **496**_b_. In other words, the dividing rib upper first edge portion **527**_b_ can extend from proximate the tip rib end **497**_b_ towards the tip end **445**. The dividing rib upper first edge portion **527**_b_ is disposed between the center divider **492**_b_ and tip end **445**.

The first channel **474**_b_ may extend throughout the turbine blade **440** in a serpentine configuration similar to the dividing rib **480**_b_ and be formed by the dividing rib **480**_b_, the skin **460**, and other internal structures in the airfoil **441**. The first channel **474**_b_ can be in flow communication with the main inlet passage **466**_b_ and main inlet **462**_b_. The first channel **474**_b_ can begin between the forward face **456** and the dividing rib **480**_b_ and disposed adjacent the main inlet **462**_b_. Alternatively, the first channel **474**_b_ can begin between the dividing rib base end **481**_b_ and the trailing edge **447**. The first channel **474**_b_ can extend to the center divider **492**_b_ while between the trailing edge **447** and the dividing rib **480**_b_. The first channel **474**_b_ can continue extending around the base rib end **491**_b_, between the dividing rib **480**_b_ and the center divider **492**_b_, to between the dividing rib **480**_b_ and the center rib **493**_b_. The first channel **474**_b_ can then extend toward the root end **444** while located between the dividing rib **480**_b_ and the center rib **493**_b_. The first channel **474**_b_ can further extend around the center rib base end **494**_b_ between the center rib **493**_b_ and the dividing rib **480**_b_, towards the tip end **445** while between the center rib **493**_b_ and the dividing rib. The first channel **474**_b_ can continue by extending towards the tip end **445** while between the center rib **493**_b_ and the dividing rib **480**_b_. The first channel **474**_b_ can further continue by extending around the center rib tip end **495**_b_ while between the center rib **493**_b_ and dividing rib **480**_b_, towards the base **442** while between the dividing rib **480**_b_ and the center rib **493**_b_. The first channel **474**_b_ can continue by extending to the center divider **492**_b_ while between the dividing rib and center rib **493**_b_. The first channel **474**_b_ can continue by extending around the tip rib end **497**_b_ while between the dividing rib and the center divider **492**_b_, to between the dividing rib **480**_b_ and the trailing edge **447**. The first **474**_b_ can further continue by extending towards the tip end **445**, between the trailing edge **447** and the dividing rib **480**_b_, and further to the tip end channel **535**.

The second channel **476**_b_ may extend throughout the turbine blade **440** in a serpentine configuration similar to the first channel **474**_b_ and be formed by the dividing rib **480**_b_, the skin **460**, and other internal structures in the airfoil **441**. The second channel **476**_b_ may be in flow communication with the main inlet **462**_b_ and the main inlet passage **466**_b_. The second channel may be in flow communication with the secondary inlet **464**_b_ and the secondary inlet passage **468**_b_. The second channel **476**_b_ can begin between the dividing rib **480**_b_ and the base rib **490**_b_ and disposed adjacent the main inlet **462**_b_. Alternatively, the second channel **476**_b_ can begin between the dividing rib base end **481**_b_ and the base rib **490**_b_. The second channel **476**_b_ can extend from between the dividing rib **480**_b_ and the base rib **490**_b_ to the center divider **492**_b_. The second channel **476**_b_ can continue extending around the base rib end **491**_b_, between the base rib **490**_b_ and the dividing rib **480**_b_, towards the base **442**. The second channel **476**_b_ can then extend further towards the root end **444**, while located between the base rib and the dividing rib **480**_b_. The second channel **476**_b_ can further extend around the center rib base end **494**_b_ between the dividing rib **480**_b_ and the root end **444**, to between the dividing rib **480**_b_ and the leading edge **446**. The second channel **476**_b_ can continue by extending to the tip center rib **498**_b_ while between the dividing rib **480**_b_ and the leading edge **446**. The second channel **476**_b_ can further continue by extending around the center rib tip end **495**_b_ while between the dividing rib **480**_b_ and the tip center rib **498**_b_, to between the tip rib **496**_b_ and the dividing rib **480**_b_. The second channel **476**_b_ can continue by extending towards the center divider **492**_b_ while between the tip rib **496**_b_ and dividing rib **480**_b_. The second channel **476**_b_ can continue by extending around the tip rib end **497**_b_ while between the tip rib **496**_b_ and the dividing rib **480**_b_, towards the tip end **445**. The second channel **476**_b_ can further continue by extending towards the tip end **445** and to the tip end channel **535**.

In an embodiment, the turbulators **482**_b_ may be disposed between the trailing edge **447** and the dividing rib **480**_b_ and between the dividing rib **480***b* and the base rib **490***b*. The turbulators **482***b* can be distributed throughout the other remaining areas of the airfoil **441** as well.

The cooling fins **486***b* may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin **460**. In an embodiment the cooling fins **486***b* are disposed between the center rib **493***b* and the leading edge **446**. The cooling fins **486***b* may be disbursed copiously throughout the airfoil **441**. In particular, the cooling fins **486***b* may be disbursed throughout the airfoil **441** so as to thermally interact with the cooling air **15** for increased cooling.

The airfoil **441** may include several air deflectors including a first edge air deflector **484***b*, a center air deflector **485***b*, and a tip air deflector **488***b* that may extend from the pressure side **448** of the skin **460** to the lift side **449** of the skin. The first edge air deflector **484***b* can be disposed proximate to the center divider **492***b* and the trailing edge **447**. The tip air deflector **488***b* can be disposed proximate to the leading edge **446** and the tip center rib **498***b*. The first edge air deflector **484***b*, center air deflector **485***b*, and tip air deflector **488***b* can have sizes and positions selected to maximize cooling in their respective locations.

INDUSTRIAL APPLICABILITY

The present disclosure generally applies to cooled turbine blades **440**, and gas turbine engines **100** having cooled turbine blades **440**. The described embodiments are not limited to use in conjunction with a particular type of gas turbine engine **100**, but rather may be applied to stationary or motive gas turbine engines, or any variant thereof. Gas turbine engines, and thus their components, may be suited for any number of industrial applications, such as, but not limited to, various aspects of the oil and natural gas industry (including include transmission, gathering, storage, withdrawal, and lifting of oil and natural gas), power generation industry, cogeneration, aerospace and transportation industry, to name a few examples.

Generally, embodiments of the presently disclosed cooled turbine blades **440** are applicable to the use, assembly, manufacture, operation, maintenance, repair, and improvement of gas turbine engines **100**, and may be used in order to improve performance and efficiency, decrease maintenance and repair, and/or lower costs. In addition, embodiments of the presently disclosed cooled turbine blades **440** may be applicable at any stage of the gas turbine engine's **100** life, from design to prototyping and first manufacture, and onward to end of life. Accordingly, the cooled turbine blades **440** may be used in a first product, as a retrofit or enhancement to existing gas turbine engine, as a preventative measure, or even in response to an event. This is particularly true as the presently disclosed cooled turbine blades **440** may conveniently include identical interfaces to be interchangeable with an earlier type of cooled turbine blades **440**.

As discussed above, the entire cooled turbine blade **440** may be cast formed. According to one embodiment, the cooled turbine blade **440** may be made from an investment casting process. For example, the entire cooled turbine blade **440** may be cast from stainless steel and/or a superalloy using a ceramic core or fugitive pattern. Accordingly, the inclusion of the dividing rib **480***a*, **480***b* is amenable to the manufacturing process. Notably, while the structures/features have been described above as discrete members for clarity, as a single casting, the structures/features may be integrated with the skin **460**. Alternately, certain structures/features may be added to a cast core, forming a composite structure.

Embodiments of the presently disclosed cooled turbine blades **440** provide for an increase in cooling capacity, which makes it more amenable to stationary gas turbine engine applications. In particular, serpentine configuration provides for improved cooling at lower spans of the airfoil and use the spent cooling air **15** from the lower span to continue and cool the upper span of the airfoil where the turbine blade **440** can tolerate higher metal temperatures.

In a disclosed embodiment, pressurized cooling air **15** is received by the base **442** of the airfoil **441**. The cooling air **15** is received from the main inlet **462***a*, **462***b* and flows through the main inlet passage **466***a*, **466***b* in a generally radial direction. From the main inlet passage **466***a*, **466***b*, the cooling air **15** is received by the first channel **474***a*, **474***b* and the second channel **476***a*, **476***b* and may follow the first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* respectively. A first turn of the first channel **474***a*, **474***b* and the second channel **476***a*, **476***b* around the base rib **490***a*, **492***b* provides increased cooling effects of the cooling air **15** as it passes through the lower span of the turbine blade **440**.

The cooling air **15** generally follows the first channel **474***a*, **474***b* and the second channel **476***a*, **476***b* along the dividing rib **480***a*, **480***b* until the first channel **474***a*, **474***b* and second channel **476***a*, **476***b* approach the tip end **445** and combine into the tip end channel **535***a*, **535***b*. Once the cooling air **15** enters the tip end channel **535***a*, **535***b* the cooling air **15** is generally directed out of the trailing edge outlet **489***a*, **489***b* or the tip opening **503***a*, **503***b*.

The first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* are configured such that cooling air **15** will pass between, along, and around the various internal structures, but generally flows in serpentine path as viewed from the side view from the base **442** back and forth toward and away from the tip end **445** (e.g., conceptually treating the camber sheet as a plane). Accordingly, the first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* may include some negligible lateral travel (e.g., into and out of the plane) associated with the general curvature of the airfoil **441**. Also, as discussed above, although the first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* are illustrated by two single representative flow lines traveling through two sections for clarity, first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* include the entire flow path carrying cooling air **15** through the airfoil **441**. With the implementation of the dividing rib **480***a*, **480***b*, the first multi-bend heat exchange path **470***a*, **470***b* and the second multi-bend heat exchange path **472***a*, **472***b* make use of the serpentine flow path with more uniform temperature distribution in comparison to single bend turbine blades. This provides for a higher cooling efficiency at lower spans and helps break up possible dead zones.

In rugged environments, certain superalloys may be selected for their resistance to particular corrosive attack. However, depending on the thermal properties of the superalloy, greater cooling may be beneficial. The described method of manufacturing a cooled turbine blade **440** provides for implementing the dividing rib **480***a*, **480***b*. In particular, the dividing rib **480***a*, **480***b* creates two channels which achieve a more uniform temperature distribution of a turbine blade and increase cooling efficiency at lower airfoil spans and could increase blade life. Moreover, the internal airfoil structures including the dividing rib **480**a, **480**b can be suitable for use in turbine blades with thin blade airfoils.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention. Accordingly, the preceding detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. In particular, the described embodiments are not limited to use in conjunction with a particular type of gas turbine engine. For example, the described embodiments may be applied to stationary or motive gas turbine engines, or any variant thereof. Furthermore, there is no intention to be bound by any theory presented in any preceding section. It is also understood that the illustrations may include exaggerated dimensions and graphical representation to better illustrate the referenced items shown, and are not consider limiting unless expressly stated as such.

It will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments. The embodiments are not limited to those that solve any or all of the stated problems or those that have any or all of the stated benefits and advantages.

What is claimed is:

1. A turbine blade for use in a gas turbine engine, the turbine blade comprising:

a base including

a root end; and

an airfoil comprising

a skin extending from the base and defining a first edge, a second edge opposite the first edge, a pressure side, and a lift side opposite the pressure side, and having a tip end opposite from the root end,

a base rib disposed within the airfoil and the base, extending from the base and into the airfoil, and having a base rib end disposed opposite from the base,

a center divider extending from adjacent the first edge towards the second edge, disposed between the base rib and the tip end,

a center rib disposed between the center divider and the second edge, extending from adjacent the center divider towards the tip end and extending from adjacent the center divider towards the root end, the center rib disposed between the root end and the tip end and at least partially between the base rib and the second edge, and having a center rib tip end disposed at the tip end of the center rib, and

a center rib base end disposed opposite from the tip end,

a tip center rib extending from adjacent the second edge towards the first edge, disposed between the center rib and the tip end,

a tip rib extending from adjacent the tip center rib, distal to the second edge, towards the base, the tip rib disposed at least partially between the center rib and the first edge, disposed between the center divider and the tip end, and having a tip rib end disposed opposite from the tip end, and

a dividing rib extending from proximate an interface of the airfoil and the base, towards the tip end while between the first edge and the base rib, to between the tip rib and the first edge and between the tip end and the center divider, and having a dividing rib tip end disposed proximate and spaced from the tip end; and

a first channel beginning proximate the interface of the airfoil and the base, the first channel extending to the center divider while between the first edge and the dividing rib, the first channel further extends around the base rib tip, between the dividing rib and the center divider, and further to between the dividing rib and the center rib, the first channel further extends toward the root end while located between the dividing rib and the center rib, the first channel further extends around the center rib base end while between the center rib and the dividing rib, towards the tip end while between the center rib and the dividing rib, the first channel further extends towards the tip end while between the center rib and the dividing rib, the first channel further extends around the center rib tip end while between the center rib and dividing rib, towards the base while between the dividing rib and the center rib, the first channel further extends to the center divider while between the dividing rib and center rib, the first channel further extends around the tip rib end while between the dividing rib and the center divider, to between the dividing rib and the first edge, the first channel further extends towards the tip end, between the first edge and the dividing rib.

2. The turbine blade of claim **1**, the turbine blade further comprising a second channel beginning proximate the interface of the airfoil and the base, the second channel extending from between the dividing rib and the base rib to the center divider, the second channel further extends around the base rib end, to between the base rib and the dividing rib, and further towards the base, the second channel further extends towards the root end while located between the base rib and the dividing rib, the second channel further extends around the center rib base end between the dividing rib and the root end, to between the dividing rib and the second edge, the second channel further extends to the tip center rib while between the dividing rib and the second edge, the second channel further extends around the center rib tip end while between the dividing rib and the tip center rib, to between the tip rib and the dividing rib, the second channel further extends towards the center divider while between the tip rib and dividing rib, the second channel further extends around the tip rib end while between the tip rib and the dividing rib, towards the tip end, the second channel further extends towards the tip end, between the dividing rib and the tip rib.

3. The turbine blade of claim **1**, wherein the center rib and the dividing rib extend into the base.

4. The turbine blade of claim **1**, the dividing rib further comprising

a dividing rib lower first edge portion extending from proximate to an interface of the airfoil and the base, towards the center divider while between the first edge and the base rib,

a dividing rib lower first edge transition portion extending from between the first edge and base rib, to between the base rib and the center divider, and further to between the base rib and the center rib,

a dividing rib lower middle portion extending from between the base rib and center rib towards the root end while located between the base rib and the center rib,

a dividing rib lower middle transition portion extending from between the base rib and the center rib, to between the center rib and the root end, and further to between the center rib and the second edge, a dividing rib second edge portion extending from between the center rib and the second edge towards the tip center rib,

a dividing rib second edge transition portion extending from between the second edge and the center rib, to between the center rib and the tip center rib, and further to between the tip rib and the center rib,

a dividing rib upper middle portion extending from between the tip rib and center rib towards the center divider,

a dividing rib upper middle transition portion extending from between the tip rib and center rib, to between the tip rib and the center divider, and further to between the tip rib and the first edge, and

a dividing rib upper first edge portion extending from between the first edge and the tip rib towards the tip end.

5. The turbine blade of claim **1**, wherein the base rib bends towards the first edge when located proximate to the interface of the airfoil and the base.

6. A turbine blade for use in a gas turbine engine, the turbine blade comprising:

a base including

a root end; and

an airfoil comprising a skin extending from the base and defining a leading edge, a trailing edge opposite from the leading edge, a pressure side, and a lift side opposite the lift side, and having

a tip end opposite from the root end,

a base rib disposed between leading edge and the trailing edge, extending from the base and towards the tip end,

a center divider extending from adjacent the leading edge towards the trailing edge, disposed between the base rib and the tip end,

a center rib disposed between the center divider and the trailing edge, extending from adjacent the center divider towards the tip end and extending from adjacent the center divider towards the root end, the center rib disposed between the root end and the tip end and at least partially between the base rib and the trailing edge,

a tip center rib extending from adjacent the trailing edge towards the leading edge, disposed between the center rib and the tip end,

a tip rib extending from adjacent the tip center rib towards the base, distal to the trailing edge, the tip rib disposed at least partially between the center rib and the leading edge, and disposed between the center divider and the tip end,

a tip wall extending from the leading edge towards the trailing edge, disposed proximate the tip end; and

a dividing rib including

a dividing rib lower first edge portion extending from proximate the interface of the airfoil and the base, towards the tip end while between the leading edge and the base rib,

a dividing rib lower first edge transition portion extending from between the leading edge and the base rib, to between the base rib and the center divider, and further to between the base rib and the center rib,

a dividing rib lower middle portion extending from between the base rib and center rib towards the root end while located between the base rib and the center rib,

a dividing rib lower middle transition portion extending from between the base rib and the center rib, to between the center rib and the root end, and further to between the center rib and the trailing edge,

a dividing rib second edge portion extending from between the center rib and the trailing edge towards the tip center rib,

a dividing rib second edge transition portion extending from between the trailing edge and the center rib, to between the center rib and the tip center rib, and further to between the tip rib and the center rib,

a dividing rib upper middle portion extending from between the tip rib and center rib towards the center divider,

a dividing rib upper middle transition portion extending from between the tip rib and center rib, to between the tip rib and the center divider, and further to between the tip rib and the leading edge, and

a dividing rib upper first edge portion extending from between the leading edge and the tip rib towards the tip wall, to between the center divider and tip wall.

7. The turbine blade of claim **6**, wherein the dividing rib lower first edge transition extends from the dividing rib lower first edge portion, the dividing rib lower middle portion extends from the dividing rib lower first edge transition portion, the dividing rib lower middle transition portion extends from the dividing rib lower middle portion, the dividing rib second edge portion extends from the dividing rib lower middle transition portion, the dividing rib second edge transition portion extends from the dividing rib second edge portion, the dividing rib upper middle portion extends from the dividing rib second edge transition portion, the dividing rib upper middle transition portion extends from the dividing rib upper portion, the dividing rib upper first edge portion extends from the dividing rib upper middle transition portion.

8. The turbine blade of claim **7**, the turbine blade further comprising

a first channel formed by the dividing rib, the skin, the leading edge, the center divider, and the center rib, and

a second channel formed by the dividing rib, the skin, the base rib, the trailing edge, the tip center rib, and the tip rib.

9. The turbine blade of claim **6**, the center divider further comprising

a center divider transition extending from the center divider to the leading edge towards the trailing edge, that is wider adjacent the leading edge than opposite from the leading edge, and

a center rib transition disposed opposite from the center divider transition, extending from the center divider to the center rib towards the leading edge, that is wider adjacent the center rib than opposite the center rib.

10. The turbine blade of claim **6**, the tip center rib further comprising

a tip center rib transition extending from the tip center rib to the trailing edge towards the leading edge, that is wider adjacent the trailing edge than opposite the trailing edge, and

a tip rib transition that is disposed opposite from the tip center rib transition that extends from the tip center rib towards the base.

11. The turbine blade of claim **8**, the turbine blade further comprising

a main inlet disposed in the base and in flow communication with the first channel and the second channel, and

a secondary inlet disposed in the base and in flow communication with the second channel.

12. The turbine blade of claim 11, the turbine blade further comprising a metering plate blocking plate disposed radially inward of the main inlet, the metering plate having

a first metering orifice sized to provide a desired amount or flow of cooling air to the first channel, and

a second metering orifice sized to provide a desired amount or flow of cooling air to the second channel.

13. The turbine blade of claim 11, wherein the dividing rib lower first edge portion extends from main inlet to between the base rib and the leading edge.

14. A turbine blade for use in a gas turbine engine, the turbine blade comprising:

a base including

a root end; and

an airfoil comprising a skin extending from the base and defining a leading edge, a trailing edge opposite the leading edge, a pressure side, and a lift side opposite the pressure side, and having

a tip end opposite from the root end,

a base rib disposed between leading edge and the trailing edge, extending from the base and towards the tip end, having a base rib end disposed opposite from the base,

a center divider extending from adjacent the trailing edge towards the leading edge, disposed between the base rib and the tip end,

a center rib disposed between the center divider and the leading edge, extending from adjacent the center divider towards the tip end and extending from proximate the center divider towards the root end and at least partially between the base rib and the leading edge, and having

a center rib tip end disposed at the tip end of the center rib, and

a center rib base end disposed opposite from the tip end,

a tip center rib extending from adjacent the leading edge towards the trailing edge, disposed between the center rib and the tip end,

a tip rib extending from adjacent the tip center rib, distal to the leading edge, towards the base, the tip rib disposed at least partially between the center rib and the trailing edge, further disposed between the center divider and the tip end, and having a tip rib end disposed opposite from the tip end,

a dividing rib extending from proximate to an interface of the airfoil and the base, towards the tip end while between the trailing edge and the base rib, to between the tip rib and the trailing edge and between the tip end and the center divider, and having a dividing rib tip end disposed proximate and spaced from the tip end,

a second channel beginning proximate the interface of the airfoil and the base, the second channel extending from between the dividing rib and the base rib to the center divider, the second channel further extends around the base rib tip, to between the base rib and the dividing rib, and further towards the base, the second channel then further extends towards the root end while located between the base rib and the dividing rib, the second channel further extends around the center rib base end between the dividing rib and the root end, to between the dividing rib and the leading edge, the second channel further extends to the tip center rib while between the dividing rib and the leading edge, the second channel further extends around the center rib tip end while between the dividing rib and the tip center rib, to between the tip rib and the dividing rib, the second channel further extends towards the center divider while between the tip rib and dividing rib, the second channel further extends around the tip rib end while between the tip rib and the dividing rib, towards the tip end, the second channel further extends towards the tip end, between the dividing rib and the tip rib.

15. The turbine blade of claim 14, the turbine blade further comprising a first channel beginning proximate the interface of the airfoil and the base, the first channel extending to the center divider while between the trailing edge and the dividing rib, the first channel further extends around the base rib tip, between the dividing rib and the center divider, and further to between the dividing rib and the center rib, the first channel further extends toward the root end while located between the dividing rib and the center rib, the first channel further extends around the center rib base end while between the center rib and the dividing rib, towards the tip end while between the center rib and the dividing rib, the first channel further extends towards the tip end while between the center rib and the dividing rib, the first channel further extends around the center rib tip end while between the center rib and dividing rib, towards the base while between the dividing rib and the center rib, the first channel further extends to the center divider while between the dividing rib and center rib, the first channel further extends around the tip rib end while between the dividing rib and the center divider, to between the dividing rib and the trailing edge, the first channel further extends towards the tip end, between the trailing edge and the dividing rib, to between the dividing rib and the tip wall.

16. The turbine blade of claim 14, the dividing rib further comprising

a dividing rib lower first edge portion extending from proximate to an interface of the airfoil and the base towards the tip end, disposed between the trailing edge and the base rib,

a dividing rib lower first edge transition portion extending from the dividing rib lower first edge portion, to between the base rib and the center divider, and further to between the base rib and the center rib,

a dividing rib lower middle portion extending from the dividing rib lower first edge transition portion towards the root end while located between the base rib and the center rib, the dividing rib lower middle portion disposed between the center divider and the root end,

a dividing rib lower middle transition portion extending from the dividing rib lower middle portion, to between the center rib and the root end, and further to between the center rib and the leading edge,

a dividing rib second edge portion extending from the dividing rib lower middle transition portion towards the tip end while between the center rib and the leading edge, the dividing rib second edge portion disposed between the root end and the tip center rib,

a dividing rib second edge transition portion extending from the dividing rib second edge portion, to between the center rib and the tip center rib, and further to between the tip rib and the center rib,

a dividing rib upper middle portion extending from the dividing rib second edge transition portion towards the center divider while between the tip rib and center rib, the dividing rib upper middle portion disposed between the tip center rib and the center divider,

a dividing rib upper middle transition portion extending from the dividing rib upper middle portion, to between the tip rib and the center divider, and further to between the tip rib and the trailing edge, and

a dividing rib upper first edge portion extending from the dividing rib upper middle transition portion towards the tip end, between the trailing edge and the tip rib.

17. The turbine blade of claim **15**, the turbine blade further comprising

a main inlet disposed in the base and in flow communication with the first channel and the second channel, and

a secondary inlet disposed in the base and in flow communication with the second channel.

18. The turbine blade of claim **17**, the turbine blade further comprising a blocking plate disposed radially inward of the secondary inlet that can restrict cooling air from entering the secondary inlet.

19. The turbine blade of claim **14**, wherein the turbine blade includes a tip opening that is defined by the space between the pressure side of the skin, the lift side of the skin, the tip center rib, and the trailing edge. The tip opening operable to allow for cooling air to escape the airfoil near the tip end.

20. The turbine blade of claim **16**, wherein the dividing rib lower first edge portion extends from adjacent the root end to between the base rib and the trailing edge.

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